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Portable Sampler for Pesticides and Semivolatile Industrial Organic Chemicals in Air

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Portable Sampler for Pesticides and Semivolatile Industrial Organic Chemicals in Air

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A battery powered, low volume air sampling system utilizing polyurethane foam (PUF) as a trapping medium has been developed and evaluated. The sampler provides air flows of up to 4 L/min, affording theoretical detection limits of less than 0.1 $\mu g/m^3$ for most chemicals tested. It is lightweight and portable and operates very quietly, which makes it ideally suited for domiciliary air sampling or as a personal air monitor. Sampling efficiencies were determined for 17 organochlorine pesticides and industrial compounds, three polychlorinated biphenyl mixtures, and 28 organophosphorus, organonitrogen, and pyrethroid pesticides. With few exceptions, these chemicals were trapped efficiently (>75%). Combination of PUF with Tenax GC in a single, reusable sampling cartridge provided for quantitative collection of the more volatile compounds.

The presence of pesticides and polychlorinated biphenyls (PCBs) in the air inside residential, office, and industrial buildings has been well documented (*1–3*). Levels of these and other toxic chemicals are typically 10 to 100 times higher indoors than in the surrounding outdoor atmosphere. Since the average resident of the United States spends an estimated 90% of the time indoors (*4*), respiratory exposure to many potentially harmful chemicals in the home and workplace may present a significant hazard to human health. With ever-growing demands for energy conservation resulting in more tightly sealed buildings and the increased use of synthetic materials in construction and furniture, the problems associated with indoor air pollution may further intensify. Recognition of these problems has resulted in the formation of a federal Interagency Research Group on Indoor Air Quality, which recently conducted its first workshop (*5*). A consensus of the workshop was that more research and development of monitoring techniques for indoor air sampling is needed.

Indoor air monitoring can be accomplished either in a stationary fashion by placement of samplers at strategic locations within the structure or through the use of portable devices worn on the person to sample air in the individual's breathing zone. Either method requires a sampler which is unobtrusive; i.e., one which is portable, operates quietly, does not get in the way of residents or workers, and places little or no burden on the site owner to maintain. If the sampler is to be worn on the person, it must be battery operated and lightweight. In this paper we report the development and evaluation of an efficient low volume air sampling system which can be used with equal ease for stationary or personal air monitoring. The method utilizes polyurethane foam as a collector and is an extension of the high volume sampling technique reported earlier by this laboratory (*6*).

EXPERIMENTAL SECTION

Materials. The polyurethane foam (PUF) used was obtained from Olympic Products Co. (Greensboro, NC) and was open-cell polyether type, density 0.022 g/cm^3. This type of foam is used for furniture upholstery, pillows, and mattresses. Cylindrical sampling plugs 22 mm diameter × 7.6 cm were cut from sheet stock with a stainless steel cutting dye. The PUF plugs were prepared for use by successive Soxhlet extraction with 5% diethyl ether in hexane until the extract yielded acceptable blank values (less than the equivalent of 10 ng/plug for a given compound or PCB mixture). Two extractions of at least 32 cycles each were usually sufficient. Tenax GC, 35–60 mesh, was obtained from Applied Science Laboratories (State College, PA) and was preextracted in the same fashion as the PUF.

All solvents were glass distilled from Burdick and Jackson (Muskegon, MI) or equivalent. All pesticides and PCBs were obtained from the Pesticides and Industrial Chemicals Reference Standards Repository, U.S. Environmental Protection Agency (Research Triangle Park, NC). Other chemicals evaluated were purchased from Aldrich Chemical Co. (Milwaukee, WI).

Apparatus. The portable air pump (Figure 1) used was a DuPont P-4000 constant flow sampling pump (E. I. du Pont de Nemours & Co., Inc., Wilmington, DE), which can be preset to provide a constant flow rate of 0.02–4.0 L/min (±5%). The pump can be programmed for predetermined sampling periods and automatically adjusts the pumping rate to maintain constant flow. It weighs 1.2 kg and can be comfortably worn on a waist belt. Rechargeable batteries will operate the pump for at least 12 h at 4 L/min on a single charge. For stationary sampling, the pump may be operated on ac current via a small charger. The pump was calibrated before use with a DuPont calibration kit (catalog no. 66-242-f-1), which consists of a soap bubble meter, flow rate gauge, and pressure-drop meter contained in a portable valise.

Most of the studies reported here were based on the use of sampling cartridge A (Figure 1), which was constructed from a simple 20 mm (i.d.) × 10 cm borosilicate glass tube drawn down to a 7 mm (o.d.) open connection for attachment to the pump. A 22 mm diameter × 7.6 cm long cylindrical PUF plug is fitted under slight compression inside the cartridge. Alternatively, two 3.8 cm long plugs separated by a stainless steel wire screen may be used. Cartridge B was designed for field use where separate collection of airborne particulate matter may be desired. It is essentially a modified screw-cap glass bottle, 20 mm (i.d.) × 8 cm total length. The threaded neck is 18 mm (i.d.) × 17 mm and the bottom has been drawn down to a 7 mm (o.d.) open tubing connector. The cartridge will accommodate a 22 mm diameter × 6 cm PUF plug. A 20-mm glass fiber (or other type) filter is held in front of the PUF vapor trap by the modified plastic screw cap with a 14 mm diameter opening. The filter is supported by a fine stainless steel screen and silicone gasket. Cartridge B was fabricated inexpensively from glass by Kontes (Vineland, NJ) but can be constructed from aluminum or Teflon. Both cartridges are lightweight (20–30 g loaded) and may be comfortably worn on the shirt collar, attached by band clips.

In order to improve the trapping of more volatile compounds, a dual-sorbent trap was devised. This trap consisted of a 0.6-g layer of Tenax-GC or other granular polymeric sorbent "sandwiched" between two 22 mm diameter × 3.8 cm PUF plugs.

Air Sampling Efficiency. The efficiency of the sampler to collect and retain chemicals in the gaseous state was tested by using the apparatus shown in Figure 2. Two modified glass sampling cartridges were connected in tandem by means of "O"-ring ball joints. Each cartridge contained a PUF plug measuring 20 mm diameter × 3.8 cm. The dual trap was attached to a modified midget impinger vapor generator to which was added a weighed quantity of the test compound or mixture in 1 mL of hexane. Dry nitrogen was drawn through the train for 4–12 h

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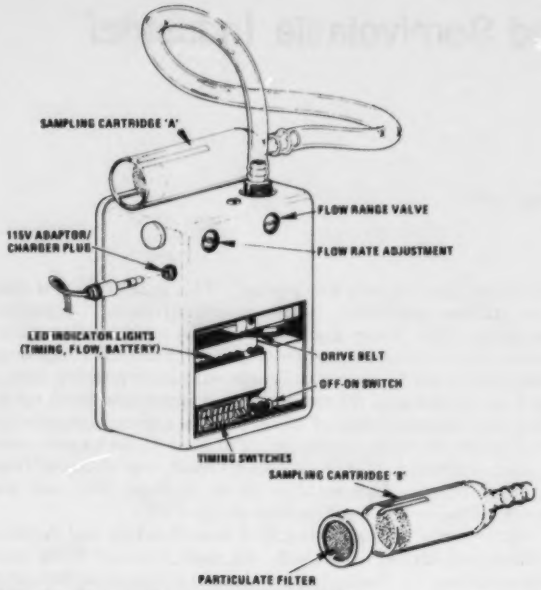

Figure 1. Air sampling pump and cartridge.

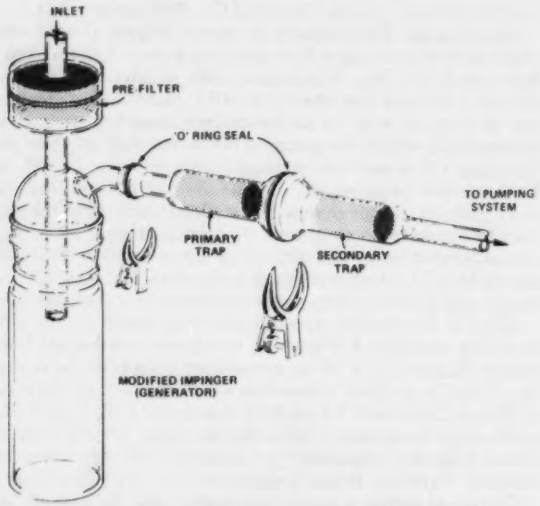

Figure 2. Apparatus for determining sampling efficiencies.

at specified flow rates, after which the impinger and two plugs were separately analyzed. Collection efficiency (CE) was defined as

$$\% \text{ CE} = \frac{W_1}{W_o - W_r} \cdot 100$$

where W_o is the original weight of chemical added to the generator (impinger), W_r is the residue left in the generator at the end of the test, and W_1 is the amount found on the first PUF trap. The quantity found in the second trap, W_2, can be used to estimate breakthrough and determine the overall % CE for both plugs. All weights were corrected for blank values. For less volatile compounds, the impinger was heated to a maximum of 40 °C to aid volatilization. A nitrogen atmosphere was used to minimize degradation.

Retention or breakthrough studies were conducted in order to estimate sampling efficiencies in cases where vaporization of the test chemical was not possible. Retention efficiencies (RE) were determined by fortifying the PUF with a known quantity of the chemical or mixture dissolved in 0.5–1.0 mL of hexane by slow, dropwise addition of the solution to the intake face of the plug. After a 2-h drying period, the fortified plug was placed in the first cartridge of the train (Figure 2) and a clean PUF plug was placed in the second cartridge. Ambient air, prefiltered through PUF, was drawn through the train at 3.8 L/min for 4 h to determine the extent of breakthrough to the second plug. For each test, control plugs were prepared in identical fashion and held under static conditions (sealed in aluminum foil) for the same period.

Analysis. PUF plugs were removed from the glass cartridges for extraction in a 125-mL Soxhlet extractor except in the case of the PUF/Tenax GC combination trap, which was placed in the extractor in an inverted position after careful cleaning of the outside. After 4–16 h of extraction with 75 mL of 5% diethyl ether in hexane (rate: 8 cycles/h), the extracts were concentrated to <5 mL under vacuum in a rotary evaporator, rinsed into a 15-mL graduated centrifuge tube, and adjusted to final volume.

All extracts were analyzed directly by gas chromatography (GC) or high-performance liquid chromatography (HPLC). GC analyses were carried out on Tracor 222 instruments equipped with pulsed, linearized ^{63}Ni electron capture (EC), flame photometric (FP), and nitrogen–phosphorus (N-P) detectors. Columns, 4 mm i.d. × 183 cm borosilicate glass, used for neutral organochlorine (OC) and organophosphorus (OP) compounds were 1.5% OV-17/1.95% OV-210 on 80/100 mesh Supelcoport, 4% SE-30/6% OV-210 on 100/120 mesh Gas Chrom Q, and 3% OV-1 on 80/100 mesh Chromosorb WHP. The carrier gas was nitrogen, 70 mL/min (85 mL/min for SE-30/OV-210). Column temperature was 200 °C except for the chlorobenzenes (100 °C). Chlorophenols were determined intact by GC on a double-support-bonded DEGS column (4 mm i.d. × 60 cm) at 175 °C according to the method of Edgerton and Moseman (*7*). Carbamates and triazines were also measured intact by GC on a 2 mm i.d. × 183 cm column of 3% OV-101 on Ultra-Bond following the procedure of Hall and Harris (*8*). The HPLC system consisted of a WISP autoinjector, Tracor 995 pumps, an LDC Spectro Monitor III UV detector, and an LDC CCM control module. Ureas and pyrethrins were analyzed by reversed-phase HPLC on a 25-cm Zorbax ODS column using 80:20 methanol:water as the solvent system and a flow rate of 2 mL/min. The UV detector was set at 245 nm.

PCB concentrations were estimated by multiple peak comparisons with the corresponding Aroclor reference standard as described elsewhere (*6*). Chlordane was determined similarly.

RESULTS AND DISCUSSION

The low volume air sampling system described here meets all of the criteria for use in monitoring pesticides, PCBs, and other semivolatile organic chemicals in indoor air and for assessment of human respiratory exposure to these compounds. It is highly portable, battery powered, and simple to operate, provides for constant air flow, and will efficiently trap most of the chemicals of concern from the air. Operating on batteries, the sampler will function efficiently for 12 h or more at flow rates up to 4 L/min to monitor as much as 3 m^3 of air. Coupled with available analytical techniques, most of the compounds of interest can be measured at levels between 1 ng/m^3 and 1 μg/m^3, well below the most stringent of the proposed criteria for safe workplace atmospheres. The sampler may be operated overnight inside private dwellings without disturbing the occupants, or it may be worn comfortably on the person.

Flow audits were made with an NBS-calibrated laminar flow element on 36 samplers operated for 12 h/day over a 3-month period. These showed a mean difference of −4.1% (std dev = 1.8%) when the pumps were set at 1.3 L/min. Extensive calibration audits have not been performed at higher flow rates, but frequent checks using the DuPont calibration kit have indicated that the flow at 4 L/min is within the ±5% tolerance specified by manufacturer.

Thirty-eight pesticides and ten chlorinated organic compounds or mixtures, representing a broad spectrum of chemical functionality and volatility, were selected for study. Collection efficiencies (CEs) were determined for all that could be adequately vaporized at temperatures below 40 °C. In cases where little if any of the material would volatilize, only retention efficiencies (REs) could be determined. REs reflect

Table I. Collection Efficiencies for Organochlorine Pesticides

compound	quantity introduced, μg	air volume, m³	collection efficiency $\bar{x}$, %	RSD, %	n
α-hexachloracyclohexane	0.005	0.9	115	8	6
γ-hexachlorocyclohexane (lindane)	0.05–1.0	0.9	91.5	8	5
technical chlordane	0.2	0.9	84.0	11	8
p,p'-DDT	0.6, 1.2	0.9	97.5	21	12
p,p'-DDE	0.2, 0.4	0.9	102	11	12
mirex	0.6, 1.2	0.9	85.9	22	7
2,4-D esters:					
isopropyl	0.5	3.6	92.0	5	12
butyl	0.5	3.6	82.0	10	11
isobutyl	0.5	3.6	79.0	20	12
isooctyl	0.5	3.6	>80[a]		

[a] Not vaporized. Value based on % RE = 81.0 (RSD = 10%, n = 6).

Table II. Collection Efficiencies for Semivolatile Organochlorine Compounds and PCB

compound or mixture	quantity introduced,[a] μg	collection efficiency $\bar{x}$, %	RSD, %	n
1,2,3-trichlorobenzene	1.0	6.6[b]	22	8
1,2,3,4-tetrachlorobenzene	1.0	62.3[b]	33	5
pentachlorobenzene	1.0	94.0	12	5
hexachlorobenzene	0.5, 1.0	94.5	8	5
hexachlorocyclopentadiene	1.0	8.3[b]	12	5
2,4,5-trichlorophenol	1.0	108	3	5
pentachlorophenol	1.0	107	16	5
Aroclor 1242	0.1	96.0	15	6
Aroclor 1254	0.1	95.0	7	6
Aroclor 1260	0.1	109	5	11

[a] Air volume 0.9 m³. [b] % CEs were 98, 98, and 97% (n = 2), respectively, for these three compounds by the PUF/Tenax GC "sandwich" trap.

Table III. Collection Efficiencies for Organophosphorus Pesticides

compound	quantity introduced,[a] μg	collection efficiency $\bar{x}$, %	RSD, %	n
dichlorvos (DDVP)	0.2	72.0	13	2
ronnel	0.2	106	8	12
chlorpyrifos	0.2	108	9	12
diazinon	1.0	84.0	18	18
methyl parathion	0.6	80.0	19	18
ethyl parathion	0.3	75.9	15	18
malathion	0.3	100[b]		

[a] Air volume = 0.9 m³. [b] Decomposed in generator; value based on % RE = 101 (RSD = 7%, n = 4).

the ability of the PUF to retain the chemicals in the air stream and theoretically represent minimum sampling efficiencies.

Collection efficiency data are presented in Tables I–IV. CE values are corrected for recovery of the test chemicals from fortified control plugs which were kept sealed for the duration of the test. Except for the carbamates and pyrethrins, static recoveries were generally greater than 80%. RE values are uncorrected for direct comparisons to static recovery values. The difference should reflect the amount of trapped material which was eluted from the plug by the air flow.

The foam 3.8-cm plugs used for determination of collection and retention efficiencies were only half the length of those for which cartridge A was designed. Therefore, the percent CEs and percent REs shown in Tables I–IV should represent minimum values when cartridge A is used with a single 7.6 cm long plug or two 3.8 cm long plugs.

The OC pesticides were collected with high efficiencies (>75%) at levels corresponding to air concentrations of 6 ng/m³ to 1.3 μg/m³ (Table I). In separate studies, these chemicals were all found to be efficiently retained on fortified PUF plugs when air was drawn through them at 3.8 L/min for 4 h (REs of 79–81% for the 2,4-D esters and 94–108% for the others). Likewise, all semivolatile chlorinated benzenes, phenols, and biphenyls (Table II) were very efficiently trapped (CEs of 94–109%) at theoretical air levels of 0.6–1.1 μg/m³. Corresponding REs ranged from 79 to 108%. Two volatile chlorobenzenes (1,2,3-tri- and 1,2,3,4-tetrachloro-) were poorly trapped by the PUF (6.6 and 62.3% CE, respectively), as was hexachlorocyclopentadiene (8.3% CE). However, in duplicate trials, all three of these compounds were quantitatively collected (98–99%) and retained (98–106%) by the PUF/Tenax-GC "sandwich" trap.

Separate trials were conducted with lindane (γ-hexachlorocyclohexane), four chlorobenzenes, 2,4,5-trichlorophenol, pentachlorophenol, and hexachlorocyclopentadiene at 1.5 L/min for 12-h sampling periods. These trials yielded percent CEs which were statistically identical with those obtained from parallel studies at 3.9 L/min for 4 h.

Multicomponent mixtures such as the Aroclors and technical chlordane are composed of compounds encompassing a range of vapor pressures. They were not uniformly vaporized from the impinger generator and may not have been trapped with equal efficiency by the PUF. Figure 3 illustrates the selective vaporization of the more volatile components (1–5) of technical chlordane from the generator. Thus the vaporized mixture entering the PUF trap was enriched with these components. The fact that the distribution of components in the material trapped on the foam closely resembles that of the standard suggests that the less volatile components of technical chlordane were more efficiently collected by the PUF. This is further supported by the overall CE of 84% for technical chlordane, while *trans*- and *cis*-chlordane (*6*, *7*) were trapped with 108% and 101% CE, respectively. Previous studies (*6*) with high-volume PUF air sampling revealed a greater than 2-fold range of CEs for components of Aroclor 1242.

GC-EC detection sensitivity varies over a wide range for the OC compounds listed in Tables I and II. However, theoretical detection limits for a 1 m³ air sample would be at least an order of magnitude lower than the concentration levels studied.

OP pesticides (Table III) were also generally efficiently collected by PUF (72–101% CE), with the relatively volatile dichlorvos (DDVP) being least efficiently trapped due to very poor retention (average 11% RE). Problems were encountered with the generation of malathion vapors due apparently to breakdown of the chemical on the glass walls of the impinger. However, malathion was quantitatively retained by the PUF and should thus be efficiently trapped. The test air concen-

Table IV. Retention and Collection Efficiencies for Carbamates, Ureas, Triazines, and Pyrethrins

compound	fortification level,[a] μg	static recovery $\bar{x}$, %	static recovery RSD, %	static recovery n	retention efficiency $\bar{x}$, %	retention efficiency RSD, %	retention efficiency n	collection efficiency $\bar{x}$, %	collection efficiency RSD, %	collection efficiency n
Carbamates										
propoxur	5	61.4	10	6	77.6	37	6	96.7	11	6
carbofuran	15	55.3	12	6	64.2	46	6	87.2	14	6
bendiocarb	50	57.3	11	6	69.8	43	6	62.1	14	6
mexacarbate	10	62.8	19	6	62.7	41	6	89.8	14	6
carbaryl	100	56.6	14	6	63.6	53	6	[b]	13	6
Ureas										
monuron	19	87.0	6	6	91.2	6	5	[c]		
diuron	20	84.1	8	6	90.0	2	5	[c]		
linuron	20	86.7	8	6	92.5	4	5	[c]		
terbuthiuron	18	85.0	8	6	88.8	8	5	[c]		
fluometuron	20	91.4	10	6	101	3	5	[c]		
chlortoluron	20	86.2	11	6	92.0	7	5	[c]		
Triazines										
simazine	10	103	6	5	101	9	6	[c]		
atrazine	10	104	7	5	98.9	7	6	[c]		
propazine	10	105	11	5	99.9	14	6	[c]		
Pyrethrins										
pyrethrin I	(9.7)[d]	90.5	10	6	95.6	22	5	[c]		
pyrethrin II	(6.1)[d]	88.6	11	6	69.9	29	5	[c]		
allethrin	25	69.2	9	5	58.3	12	6	[c]		
d-trans-allethrin	25	76.8	9	6	74.4	9	5	[c]		
dicrotophos	25	72.0	22	6	71.7	8	5	[c]		
resmethrin	25	76.5	14	6	66.7	14	6	[c]		
fenvalerate	25	87.9	3	6	57.2	20	3	[c]		

[a] Air volume 0.9 m³. [b] Decomposed in generator. [c] Not vaporized. [d] Estimated on the basis of 20 μg of pyrethrin with a composition of 48.4% and 30.3% by weight of pyrethrins I and II, respectively.

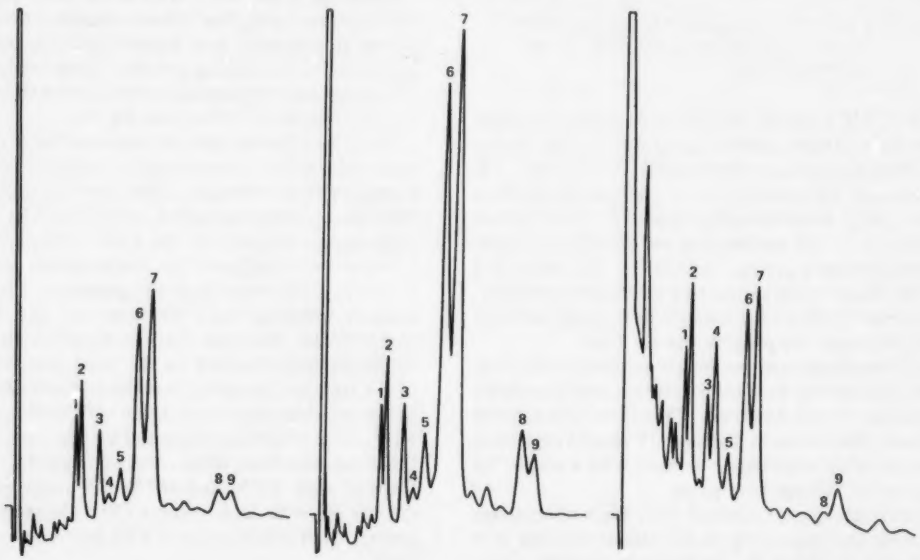

Figure 3. Electron capture gas chromatograms showing selective vaporization of technical chlordane and nonuniform trapping efficiencies of the components on polyurethane foam (after 4 h at 4 L/min). Attenuations are not the same.

trations for the OP compounds were 0.2–1.1 μg/m³, or about 10 times the practical lower limit of detection (LLD) for a 1-m³ sample.

Carbamate pesticides (Table IV) were collected with 62–97% CE (63–78% RE) at air levels of 5.6–111 μg/m³. Carbaryl was lost from the generator but was not found (<10%) on the PUF. Again, chemical breakdown is suspected. Analytical sensitivity restricts the LLD to ca. 1 μg/m³ for 1 m³ of air. Pyrethrum (EPA catalog no. 5940), which is a botanical insecticide consisting primarily of esters of pyrethrolone and cinerolone keto alcohols and chrysanthemic acids, was also evaluated (Table IV). Pyrethrin I and II, which make up 48.4% and 30.3% by weight of the mixture, were selected for quantification at air levels corresponding to 10.1 and 6.8 μg/m³, respectively (22.2 μg/m³ for pyrethrum). While these two esters could not be sufficiently vaporized to determine CEs, REs were measured at 96% for pyrethrin I and 70% for pyrethrin II. Several other pyrethrins were also

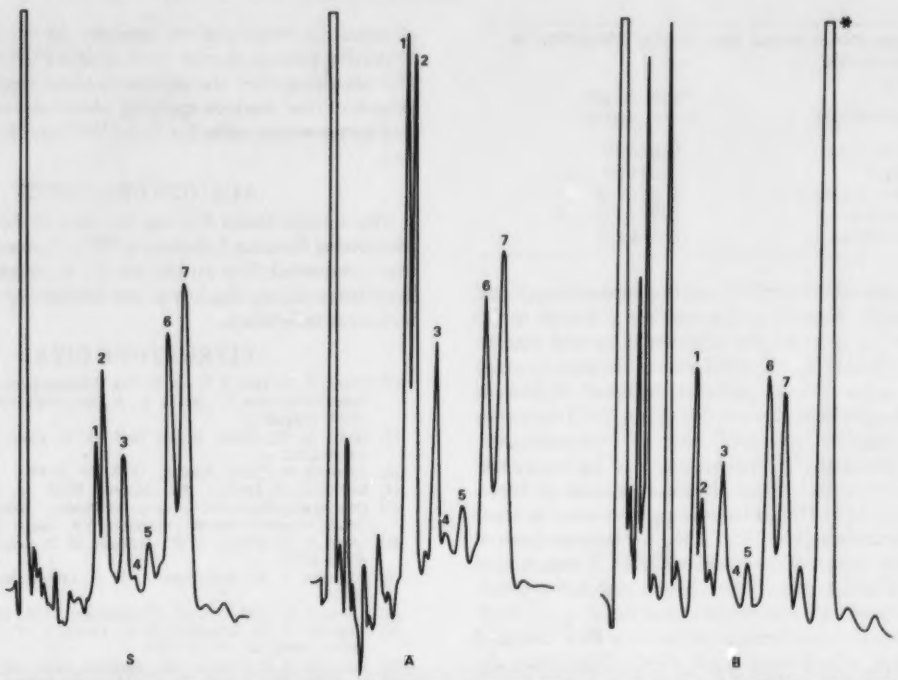

Figure 4. Electron capture gas chromatograms of chlordane components collected from domiciliary air. S is the technical chlordane reference standard; A was collected from a domicile treated in 1974; domicile B was last treated in 1960. Both homes were sampled in mid-1978. The off-scale peak denoted with the asterisk corresponds to dieldrin. Attenuations are not the same.

studied. Retention values of 57–74% (Table IV) should reflect similar or better collection efficiencies for these compounds if present in air as vapors. Use of GC-EC should give LLDs of 1 $\mu g/m^3$ or lower for 1-m^3 air samples.

The remainder of the pesticides studied also could not be vaporized at temperatures under 40 °C. Retention measurements, however, suggest that both the ureas (89–101% RE) and triazines (99–101% RE) would be quantitatively trapped on PUF if present in air (Table IV). These two groups of insecticides should be detectable at 1 $\mu g/m^3$ or less in 1 m^3 air sampler when an N-P detector is used.

In order to determine the storage stability of PUF cartridges after use for sampling, 27 different pesticides and industrial chemicals were tested for retention by the foam under adverse conditions. Fortified cartridges were stored loosely wrapped in aluminum foil in the trunk of an automobile parked in an unshaded parking lot for 15 days during July and August. Ambient maximum daytime temperatures averaged 32 °C. As can be seen from Table V, nearly all of the dichlorovos and significant percentages of ronnel and 1,3,5-trichlorobenzene were lost during storage. Other losses were relatively small considering the severity of conditions. Retentions of these chemicals by the PUF/Tenax GC cartridge were not studied. In practice, it is suggested that sampling cartridges be sealed in glass jars provided with Teflon-lined screw caps immediately before and after use and be stored under refrigeration for a maximum of 30 days prior to extraction and analysis.

Table V. Storage Stabilities of Fortified PUF Cartridges under Adverse Conditions

	amt recovered					
	day 0			day 15		
compound	$\bar{x}$, %	RSD, %	n	$\bar{x}$, %	RSD, %	n
α-hexachlorocyclohexane	90	10	6	87	28	6
β-hexachlorocyclohexane				86	30	6
γ-hexachlorocyclohexane	100	6	4	89	29	6
heptachlor				78	13	6
endosulfan I				117	19	6
mirex	89	1	4	116	17	6
1,3,5-trichlorobenzene				57	18	6
1,2,3,4-tetrachlorobenzene	88	7	4	76	12	6
pentachlorobenzene	93	6	4	78	15	6
hexachlorobenzene	98	7	4	98	7	6
2,4-dichlorophenol				88	19	6
2,4,6-trichlorophenol	96	4	4	94	48	6
pentachlorophenol	110	8	4	80	23	6
pentachloronitrobenzene				87	16	6
dichlorvos	70	12	3	4	187	6
ronnel	91	9	3	56	13	6
chlorpyriofos	89	4	3	76	13	6
diazinon	79	10	8	101	15	6
methyl parathion	80	14	8	76	13	6
ethyl parathion	80	14	8	88	11	6

APPLICATIONS

The low volume air sampling system described here is particularly useful for sampling the air inside domiciles for pesticide residues. Monitoring data collected during the past year have revealed technical chlordane in the air inside most private dwellings at levels ranging from 0.2 to 5.5 $\mu g/m^3$. Of interest is the comparison of air samples collected in two homes, one of which had not been treated for termite protection for nearly 2 decades. The gas chromatograms of these samples, shown in Figure 4, show the distinct presence of technical chlordane (corresponding to 1.1 $\mu g/m^3$) in the older dwelling (B), while the chlordane mixture found in the newer house (A), treated 4 years before the sampling, appears to be much richer in the more volatile components. Quantified as technical chlordane, the air in house A contained 3.2 $\mu g/m^3$ of the termitacide. Note the correspondingly large quantity of dieldrin in house B and its absence in A. The latter pesticide was commonly used as a termitacide some years ago. Both samples were collected at 2.5 L/min over 8-h periods (midnight to 8:00 a.m.) with PUF in cartridge A.

Many homeowners contract with pest-control services for periodic application of insecticides to the baseboards and

Table VI. Organophosphorus Insecticides Identified in Residential Indoor Air

insecticide	range of air concn, $\mu g/m^3$
dichlorvos	0.05–28
ronnel	0.01–10
chloropyrifos	0.01–7.0
diazinon	0.01–2.0
malathion	0.10–1.0

inside kitchen cabinets to control crawling insects (crack and crevice treatment). Sampling in a number of homes under such treatment has revealed the presence of several insecticides in the air (Table VI). Typical levels encountered range from 0.01 to 5 $\mu g/m^3$. In one instance, however, dichlorvos was found at 28 $\mu g/m^3$ and chlorpyrifos at 7 $\mu g/m^3$ 3 days after treatment, as a result of over-application of these pesticides.

The growing popularity of "build-it-yourself" log homes has created another potential indoor air contamination problem. Pentachlorophenol (PCP) has been commonly used to treat the logs used for construction, and since the bare surfaces of these logs usually comprise the inside walls, PCP vapors may readily enter the indoor atmosphere. In one such home, which was about 6 years old, air concentrations of 0.3–2 $\mu g/m^3$ PCP were found. The residents exhibited urinary PCP levels of 132 and 316 ng/g, which were much higher than those observed in the general population (*9*).

PCBs are found ubiquitously in the indoor air, particularly in kitchens. PCB levels found in private dwellings by this laboratory have been in the 0.1–0.5 $\mu g/m^3$ range as opposed to an average of 4 ng/m^3 in the surrounding outdoor air (*10*).

This laboratory has recently begun a national survey to assess the ubiquity of pesticides and other semivolatile organic chemicals in domicillary air (*11*). Homes were selected in both industrialized urban and rural areas for study. Calibrated, preset pumps and sampling cartridges are sent by mail to the residents, along with instructions for collection and return of the samples. A questionnaire concerning the use of chemicals in and around the house, the type of construction, and air ventilation systems was developed. The survey has proceeded very smoothly over the first 6 months, with no problems attendant to shipment, handling, or collection of the samples.

Use of the system for personal respiratory exposure assessment has also been proven in the field. This laboratory successfully employed the sampler on workers to monitor breathing zone air during cleanup of a PCB spill (*12*). Davis (*13*) has also applied the sampler to assess respiratory exposure of agricultural workers applying phosalone in apple orchards and homeowners using 2,4-D for lawn and garden weed control.

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